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Evaluating Human Operator Performance in a Fully Immersive Virtual Reality Environment Dr. J. Bernard, Iowa State University

Abstract

The Virtual Reality Applications Center is a national leader in the increasingly important field of applications of virtual reality to the challenges of engineering and science.

This DURIP contract provided peripheral equipment for VRAC's C6, a 360-degree immersion device used to display synthetic environments in real time. C6 includes six stereoscopic screens, a three-dimensional sound system, and wireless technologies.

C6, which cost over \$5 million to design and build, was made possible by support from the Air Force of Scientific Research, the National Science Foundation, Iowa State University and private industry. DURIP funds helped purchase a tracking system, networking hardware, and storage devices crucial to the operation of the system. We are now using the C6 on two major defense related projects applying virtual reality interfaces to improve operational readiness and situational awareness. The first of these projects, sponsored by the Air Force Research Lab's Human Effectiveness Directorate, is investigating the use of collaborative computer immersion to recreate a Joint Battlespace. The second is a multi-year collaboration between a VRAC research team, the Iowa National Guard, and the Iowa Technology Center. The objective of this effort is to investigate, create and evaluate the use of immersive interfaces as tools to improve the operational readiness of Iowa National Guard staff, both Army and Air.

Evaluating Human Operator Performance in a Fully Immersive Virtual Reality Environment

Sponsored by: Department of the Air Force Office of Scientific Research

F49620-00-1-0267

Final Technical Report

Jim Bernard, Director Carolina Cruz Neira, Associate Director

Virtual Reality Applications Center Iowa State University

March 15, 2002

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1.0 Introduction

The Virtual Reality Applications Center is an interdisciplinary research center administered by the Institute for Physical Research and Technology at Iowa State University. VRAC has become a national leader in the increasingly important field of applications of virtual reality to the challenges of engineering and science.

VRAC is committed to providing our researchers with the widest possible range of immersive environments so we can assess, as part of our research, the appropriate level of immersion for each task. To that end, VRAC equipment currently on line includes:

Fieldview Computers less Pointer Devices (2) ersion Interface Boxes (3) Fluent 1 SGI Onyx2 with six IR2 Engines (24 ersion Probe I-DEAS R12000 Processors) a 560 6DOF Manipulators (2) IRIS CaseVision/Workshop 2 SGI Power ONYX Multi-Pipe Infinite Level Control Consoles (2) **IRIS Inventor** Reality2 Engines on Platform: 6 DOF w/2000 lb. capacity, IRIS Performer (12 R10000 Processors ea.) approx +/-1 ft. travel in each direction, +/-Transom Jack 4 SGI Dual Processor Octane MXI 30 degrees per axis MATLAB 2 SGI ONYX Reality Engine2 ModelGen, MultiGen II 2 SGI Origin 200 Multigen Creator Video Equipment 4 SGI O2s PhotoShop 1 SGI Challenge DM 6 Barco Graphics 909 Projectors **Polytrans** 11 SGI Indys 5 Barco Graphics 1208 Projectors **ProEngineer** 1 8x8 Video/Audio Extron Switcher 6 PC systems SAMM 1 16x16 Extron Audio switcher Starcd VR Peripherals 1 32x32 Extron video switcher Softimage 26 RGB 112 Extron Das kible Screen Configuration Virtual Reality Softimage XSI 13 Cybex Longviews (copper) System MD-Flex Barco Reality 909 Base VisLab 10 Lightwave VDE (fiber) Proposal VR Juggler JVC CR-850U, 3/4" VCR ot Micro Movemaster EX MELFA Voxmap PointShell JVC BR-S811U, SVHS/VHS VCR sion Datavisor HMD WorldToolkit JVC VM-R190SU, Color Monitor ual Research V8 HMD sAble Technologies 1.5A PHANTOM Haptic Sony Trinitron, Color Monitor Software ual Technologies Cyberglove espace Labs Pinch Gloves (5 sets) ACIS espace Labs BOOM3C Adams eoGraphics CrystalEyes Stereo Glasses AudioWorks Vision Stereo Glasses **ANSYS** tial Systems Powerball DADS DragonDictate itech 3D Mouse itech Position Head Tracker Ensight ension Technologies Flock of Birds (3) tion Star Trackers (2)

VRAC supports two different head mounted displays, an nVision VGA Datavisor HMD and a Virtual Research V8 HMD. VRAC has also recently added a Barco Baron stereoscopic projection table providing portable high resolution stereoscopic display on a 60-inch rearprojected screen. The Baron table is a desk size device that can be oriented in any position from traditional desk orientation to vertically. The projection surface is tracked and provides real time 3D graphic display.

To provide full body immersion, VRAC has two state of the art immersive rooms, the C4 and the C6 and a 250 seat stereo projection auditorium:

- The C4, which includes three walls and a floor supporting real time display. The C4 has a flexible configuration the side walls can be set at any angle with the front wall from ninety degrees, the traditional CAVE configuration, to a thirty-six foot long flat wall.
- The C6, our most immersive environment. The C6 is a ten foot by ten foot cube which surrounds its users on all sides with real time 3D interactive graphics.
- The Lee Liu Auditorium. This unique auditorium uses passive stereo to display two simultaneous side-by-side video signals in 3D to an audience of up to 250 people.

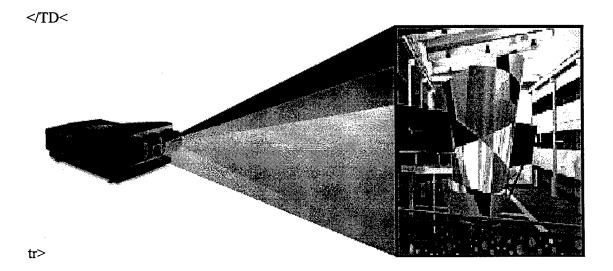
This equipment now supports the research of about 25 faculty researchers and about 75 graduate students. Total dollar value of ongoing research projects in VRAC is just over \$10 million. The Appendix lists ongoing research contracts and their principal investigators.

By most any measure, VRAC is now a world leader in VR applications. Attaining such a position is the work product of many people here at ISU plus the help of many sponsors who have shared our vision and provided resources to support our work. We are grateful to AFOSR for their continuing support.

This DURIP contract provided peripheral equipment for the C6. The next section of this report provides some context by describing the C6 and gives details of how the AFOSR support was used. Then section 3 of this report shows how this equipment is supporting defense applications.

2.0 The C6-a Fully Immersive Virtual Reality Environment

The C6 is a 360-degree immersion device used to display synthetic environments. It is based on research conducted by Dr. Carolina Cruz-Neira. The device is comprised of six stereoscopic screens, a three-dimensional sound system, and wireless technologies. Using this device, a user is able navigate through and manipulate virtual worlds. The C6 debuted on June 19, 2000.



The user stands in a 10 by 10 by 10 foot arena with rear-projected screens. Because space is a limitation, the ceiling and floor images from the projectors are reflected off of mirrors before reaching the screens. The C6 framework was designed by MechDyne and Iowa State University researchers.

The computer image generator system is a <u>SGI Onyx2 InfiniteReality2 Monster</u>. It includes six InfiniteReality graphic displays, 24 R12000 processors, 12 gigabytes of memory, and access to large disk I/O and gigabit ethernet networking. The Ascension Technologies wireless MotionStar magnetic tracker is used to monitor the user's position and orientation. This tracker maintains the user's current position used to calculate a true stereoscopic perspective view while allowing one to freely move into and around objects that appear within the virtual space. The tracker also tracks input devices, such as a wireless wand or glove. Stereoscopic perception is achieved using light-weight liquid-crystal active polarized shutter glasses. Speakers are mounted around the C6, giving participants the added sense of immersion through surround and localized sound.

The total cost of the design and build of the C6 was over \$5 million. This was made possible by support from:

- Air Force Office of Scientific Research
- Ascension Technologies
- Barco
- Boeing Company
- College of Engineering, ISU
- Deere & Company
- Institute for Physical Research & Technology (IPRT), ISU
- Iowa State University
- MechDyne Corporation
- National Science Foundation
- Procter & Gamble
- Silicon Graphics, Inc.
- And the students, faculty and staff of VRAC

AFOSR provided \$216K for C6 through this DURIP grant. With these funds we purchased:

- Motion Star Wireless 6-DOF tracking system
- Fibre channel disk chassis, includes:
 - o second fibre channel loop,
 - o controller card,
 - o power supply,
 - o rackmount original fibre channel raid vault,
 - o ten 36GB 7200 RPM Dual port fibre channel raid disk for origin FC raid
- Sony Betacam recorder/player
- Video camera
- 2 NTSC converters
- SGI Origin 200 System
- Fiberoptic cable
- Video/audio keyboard serial extension units (11)

- Extron video matrix switcher
- Extron video converters
- Extron audio switcher
- Pinch Glove System
- 8 port Ethernet S10 Terminal Server

3.0 Defense-Related work in the C6

Researchers at VRAC are working on two major defense related projects applying virtual reality interfaces to improve operational readiness and situational awareness. The first of these projects, sponsored by the Air Force Research Lab's Human Effectiveness Directorate, is a two-year investigation of the use of collaborative computer immersion to recreate a Joint Battlespace. The Virtual Battlespace currently under development is a platform for experimentation to determine the positive impact that immersion can have on battlespace management. The project objective is the development and evaluation of a data synthesis and visualization system for battle managers. The system facilitates multi-user, collaborative interaction between participants at a variety of levels of immersion.

The current phase of the investigation involves the development of a multi-user, collaborative system to allow interaction between participants at a variety of levels of immersion. The system will facilitate simultaneous interaction between multiple participants, playing distinct roles at distinct levels of immersion. Combining a traditional 2D desktop user, a user at an immersive desk, a fully immersed user in the C4 or C6, and a group of from 10-200 users in the VRAC stereo auditorium into a common environment will provide us a test bed to evaluate how levels of immersion can be used to increase task performance in a battle environment. Some initial results of this work have been summarized in a paper to be presented at this years International IITSEC conference in Lille, France. (Innovative C2 Training Solutions For Air Force Modular Control Systems, Brooks, Breitbach, George)

The second project is a multi-year collaboration between a VRAC research team, the Iowa National Guard and the Iowa Technology Center. The objective of this effort is to investigate, create and evaluate the use of immersive interfaces as tools to improve the operational readiness of Iowa National Guard staff, both Army and Air. Working with domain experts assembled by the Guard and the Iowa Technology Center, Iowa State University (ISU) is leveraging the considerable hardware, software and intellectual resources of ISU's Virtual Reality Applications Center (VRAC) to develop immersive training applications that provide Iowa Guard personnel with a greater breadth and depth of situational experience than would be possible without simulation. Using state of the art computer visualization, ISU is showing how the next generation of human-computer interfaces can be incorporated as an integral and effective component of the system for preparing Iowa Guard personnel for their role in the warfighting machine of the coming decades. The effort is currently directed towards training in the area of command and control, providing Iowa Guard personnel with comprehensive and flexible training simulations. The result will be more realistic training that is cost effective.

4.0 Summary

The purchase of tracking gear and other equipment through DURIP support helped bring the C6 on line in June 2000. Since that time, work with the C6 and the other VRAC immersive environments have increased to provide support for a wide range of ongoing work, including exciting and innovative defense contracts.

We are grateful to AFOSR for their continuing support.

Appendix

Ongoing Research Projects

Sponsor	PI	Term	Title	Co-PIs
			A Virtual Reality	
			Applications	
Air Force Office		4/1/2001	Facility for	
of Scientific		to	Visualization of	C. Cruz-
Research	James Bernard	3/31/2002	Joint Battlespace	Neira
Air Force		8/21/2000		C. Cruz-
Research Lab		to	Visualization of the	Neira; HA.
(AFRL/IFB)	James Bernard	12/31/2002	Joint Battlespace	Pham
Air Force	Junios Bornara	2/22/2002	Visualization of the	C. Cruz-
Research Lab		to	Joint Battlespace	Neira; A.
(AFRL/IFB)	James Bernard	12/31/2002	(continuation)	Sannier
(APRL/IPD)	James Demard	12/31/2002		Samuel
			Computational Modeling of a	
		8/15/2000	Tangentially Fired	
	Kenneth M.		Pulverized Coal	
Alliant Engage		to 8/14/2003	Furnace: Phase 2	
Alliant Energy	Bryden	0/14/2003		
		,	Computational	
		11/1/1000	Modeling of a	
	77 (1. 3.4	11/1/1998	Tangentially Fired	
A 111	Kenneth M.	to	Pulverized Coal	
Alliant Power	Bryden	12/31/1999	Furnace: Phase I	
	a a	9/22/2000	Immersive	
D 11 /m / GOL 6	Carolina Cruz-	to	Collaborative	
Battelle/TACOM	Neira	11/20/2001	Environments	
			Comparative	
	ļ		Visualization of	
			Experimental and	
			Computational	
Bechtel BWXT		07/31/01-	Biomass Separation	
Idaho, LLC	Greg Luecke	12/31/01	Data	
	1		A Two-tier	
			Computation and	
		10/1/1999	Visualization	
Cornell	Carolina Cruz-	to	Facility for	
University (NSF)	Neira	9/30/2002	Multiscale Problems	
			Synthetic	K. M.
			Environments as	Bryden; D.
			Enabling	Cook; C.
		11/1/2001	Technology for	Cruz-Neira;
Deere &	1	to	Product	J. Dickerson
Company	James Bernard	10/31/2005	Development: Phase	A. Kelkar;

			3 (continuation)	G. Luecke;
			,	J. Vance
				K. M.
			Crathatia	I
			Synthetic Environments as	Bryden; D.
				Cook; C.
			Enabling Tackmalager for	Cruz-Neira;
		11/1/2001	Technology for Product	J. Dickerson;
Deere &		11/1/2001		A. Kelkar;
· ·	 	to	Development: Phase	G. Luecke; J.
Company	James Bernard	10/31/2002	3	Vance
	77 136	10/1/1999		
Department of	Kenneth M.	to	Development of	
Energy	Bryden	9/30/2002	Virtual Power Plants	
		5/6/1998	Evaluating the Use	
Ford Motor		to	of Haptics in Virtual	
Company	Judy Vance	9/9/2001	CAD Tasks	
		8/15/2001	Development of	
	Kenneth M.	to	Rapid Solutions for	
Fuel Tech, Inc.	Bryden	8/15/2005	Reacting Flows	
			Learner	
Indian Hills		8/15/2001	Connections in	
Community	Kenneth M.	to	Biotechnology:	1
College (NSF)	Bryden	6/30/2004	Virtual Bioprocess	
			Military	
Iowa Department		4/1/2001	Applications of	J. Bernard;
of Public		to	Immersive	C. Cruz-
Defense	Adrian Sannier	9/30/2001	Environments	Neira
			An Atonal	D. Ashlock;
			Approach to	K. M.
		11/1/2001	Sonification of	Bryden; A.
		to	Scientific and	Sannier; P.
IPRT	Kris Bryden	6/30/2003	Engineering Data	Schnabel
			MEMS Fabrication,	
		1	Assembly,	1
			Performance, and	
		11/1/2001	Cost Tradeoffs with	
1		to	Virtual Reality	
IPRT	Li Cao	6/30/2002	Design Tools	
			Virtual Religion:	
			Integrating	
			Information	
ISU - Center for		7/1/2001	Technology into the	
Teaching	A. Whitney	to	Religious Studies	C. Cruz-
Excellence	Sanford	6/30/2001	Curriculum	Neira

Research Initiation Grants Competition Anne Deane I/1/02- I2/31/02 Initiation Grants Synthetic Environments as Enabling Technology for Product Development: Phase II Cruz-Neira Phase II Cruz-Neira Phase II Cruz-Neira Cruz-Neira Control Surfaces Initiation Grants Company James Bernard I/1/2001 Iohn Deere Foundation Initiation Grants Initiation	ISU-Special				
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	Foundation	Judy Vance	7/31/2002	Teaching	

•			Interactive Product	
		10/1/2000	Development in a	
National Science		to	Virtual Environment	
Foundation	Judy Vance	9/30/2003	Utilizing Haptics	
		2.00,200	Interactive Product	
			Development in a	
		8/1/2001		
N 10 .			Virtual Environment	
National Science		to	Utilizing Haptics	
Foundation	Judy Vance	9/30/2003	(RET)	
			Wireless	
	,		Multimedia	
		1/1/2001	Communications for	D. Rover; C.
National Science		to	Virtual	Cruz-Neira;
Foundation	Julie Dickerson	12/31/2003	Environments	R. Weber
			A Virtual Tornadic	
,			Thunderstorm to	
			Enable Student-	
			centered Learning	
			About Complex	
		2/1/2002	Storm-Scale	C. Cruz-
National Science		to	Atmospheric	Neira; C.
Foundation	William Gallus	1/31/2003	Dynamics	Cervato
			Interservice/Industry	
National			Training, Simulation	
Training		8/15/2000	& Education	
Systems	Carolina Cruz-	to	Conference	
Association	Neira	8/14/2001	Scholarship	
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National				
i l		8/16/2001	Training, Simulation	
Training	G 1: G		& Education	
Systems	Carolina Cruz-	to	Conference	
Association	Neira	8/15/2002	Scholarship	
			Ultra Low Power	
			Enabling	
		1	Technologies for	
			Adaptive	
			Reconfigurable	
		8/16/2000	Power Aware	
Nonvolatile		to	Computing and	
Electronics, Inc.	Robert Weber	12/31/2001	Communications	ļ
		2/21/2000	Visualization of	
		1 .	Gene Expression]
Pioneer Hi-Bred	Don Ashlasis	to	•	E Wantels
Fioneer Hi-Bred	Dan Ashlock	12/31/2001	Data	E. Wurtele
		0/4/0000	Automatic Control	
		2/4/2000	for Operator Assist	
	1	to	in Heavy-load	
Positech Corp	Greg Luecke	5/14/2001	Handling: Phase II	

	1		Bioinformatic Tools	
			for Extraction and	D. Berleant;
Procter &		8/3/2000	Modeling of Signal	J. Dickerson;
Gamble		to	Transduction	R. Maddux;
	Dan Ashlock	12/31/2002	Networks	E. Wurtele
Company	Dali Asiliock	12/31/2002		E. Wuitele
D		2/1/2002	Exploration of	
Procter &		2/1/2002	Finite Element	
Gamble	7 1 77	to	Analysis Data in a	
Company	Judy Vance	1/31/2003	Virtual Environment	
			Virtual Reality	
Procter &		5/1/2000	Environment for	
Gamble		to	Fluid Particle	
Company	Judy Vance	10/31/2001	Simulation	
			Virtual Reality	
			Environment for	
Procter &		9/1/2000	Fluid Particle	
Gamble		to	Simulation	
Company	Judy Vance	6/30/2001	(continuation)	
Procter &		10/20/1997	Virtual Prototyping	
Gamble		to	for Interpretation of	
Company	Judy Vance	6/30/2001	Analysis Data	
			Advanced Simulator	
			Networking for	
			Vehicle and	
		8/1/2000	Equipment	C. Cruz-
University of		to	Distributed Product	Neira; K. M.
Iowa/NADS	James Bernard	7/31/2002	Design	Bryden
	:		Multi-Component	
			Harvesting	
		6/21/2001	Equipment for	
US Dept. of	Kenneth M.	to	Inexpensive Sugars	
Energy	Bryden	9/30/2004	from Crop Residues	F. Battaglia
			Analysis and	8
		-	Implementation of a	
		4/28/2001	Tracking Mobile	
Winegard		to	Television Receiver	
Company	Greg Luecke	4/27/2002	(continuation)	
Company	STOR DUCORO	112112002	Analysis and	
		4/9/1999	Implementation of a	
Winegard		to	Tracking Mobile	
	Greg Luecke	4/27/2000	Television Receiver	1
Company	Oleg Luccke	14/2//2000	1 clevision Receiver	
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